Renewable Energies - between Climate Protection and Nature Conservation?

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Abstract

The use of renewable energies is considered as a key strategy for achieving global CO_2-reduction targets. In countries like Germany, where policy support programmes stimulated a dynamic growth of renewables, we had to observe also increasing public concern towards the impacts from RES-technologies – in particular wind turbines - on ecosystems and the natural scenery, leading to the question on whether the contribution of renewables to climate protection is at the expense of nature conservation. Taking Germany as an example, we quantified potential limitations in the RES-potential from a broad range of nature conservation safeguard subjects. Results show that in Germany the target for expanding the share of renewables from currently 3% of primary energy consumption to 50% in 2050 can be realised without getting in conflict with nature conservation requirements. Potential areas of conflict between the use of renewables and nature conservation however exist, and constraints from a nature conservation perspective shall be carefully respected when designing RES strategies.

Key words: renewable energy, nature conservation, renewable energy potential

1 Introduction

Energy and environment – on the international policy agenda this potential area of conflict is very much dominated by the issue of global climate change, and the global efforts to curb CO_2 emissions. As a response to the threat of climate change, many countries committed themselves to CO_2-reduction targets, and launched ambitious programmes for supporting renewable energy sources (RES) to achieve these targets. However, in some countries like Germany, in which the successful implementation of RES-support programmes resulted in a fast growing and by now visible share of RES to energy supply, we also observe an increasing concern towards potential negative effects of RES-technologies on local scale ecosystems, in particular from wind energy. Are we facing a potential conflict between climate protection on the one hand, and nature conservation on the other, which has been ignored so far when defining long term energy strategies set up to reduce CO_2 emissions? And does this potential conflict actually challenge the envisaged expansion of renewable energies? To get a better understanding on how nature conservation constraints might affect the expansion of renewable energies, the German Federal Ministry for the Environment, Nature Conservation and Reactor Safety commissioned a study to define strategies for an 'Ecologically Optimised Extension of Renewable Energy Utilization in Germany' [1].

While under the Kyoto protocol Germany is expected to reduce its greenhouse gas emissions by 21% by 2008/2012 (compared to the 1990 emission level), the German Government set out the far reaching target of bringing down CO_2 emissions by 80% until the mid of the century to contribute to a stabilisation of

CO_2 concentration in the atmosphere. Besides of energy efficiency measures, the increasing use of renewable energy shall help to achieve this target – by 2050 renewable energy sources are expected to supply half of the energy demand in Germany. The German Renewable Energy Sources Act, which guarantees fixed feed-in tariffs for renewable energy sources, successfully supported a massive growth of RES installations in Germany over the last decade, resulting in the increase of RES to electricity generation from 4% in 1990 to 10% in the first half of 2004. This increase resulted primarily from the fast growing installation of wind turbines, which in 2003 reached an installed capacity of 14,600 MW. This impressive growth of wind capacity however went along with an increasing public opposition against wind energy, emanating from local initiatives concerned about the intrusion of local ecosystems and the natural scenery by the installation of new wind turbines. If not sited in a careful way, large PV installations on the 'green field', which since the beginning of 2004 are also qualified for receiving feed-in tariffs under the German Renewable Energy Sources Act, are a potential source for further public opposition, running the risk of affecting the positive image of photovoltaics as 'the' symbol for renewables in Germany.

If there is a real conflict between the use of renewable energy sources and nature conservation, it has to be taken seriously, as renewables need full public support and social acceptance to achieve the long term goal of 50% contribution to total energy supply. Currently renewable energy sources only provide 3% to primary energy supply in Germany, so there is still a long way to go, which requires a careful and responsible development of any long term strategies for the employment of renewable energy sources.

2 Approach

National or regional CO_2-abatement strategies are derived from long term energy system scenario modelling. The problem in addressing nature conservation issues on the same level results from the dedicated site specific characteristics of ecosystem impacts, which are determined by highly site dependent parameters (e.g. soil characteristics, vegetation, etc.). While a site specific environmental impact assessment is most often required during the licensing and siting procedure for a specific facility, such impacts cannot be addressed in energy system models, as these models are not designed to provide the spatial resolution required to analyse local scale impacts at individual sites.

To understand how nature conservation aspects affect long term strategies on the use of renewable energies in Germany, we used as a starting point a set of normative scenarios which aim at an 80% reduction of CO_2-emissions in Germany by 2050 (see [1]). Nature conservation constraints are introduced by defining two different alternative renewable energy potentials, which are derived from the technical/structural renewable energy potentials in Germany, and from the application of various nature conservation criteria on these potentials. The alternative called ‘Basis’ reflects the technical/structural exploitable RES potential under consideration of minimum nature conservation requirements, like e.g. the exclusion of wind turbines in nature conservation areas. Under the second alternative called ‘NatureConservationPlus’ we identified a RES potential which is available on the long term even under stringent nature conservation constraints.

Potential limitations of nature conservation criteria on the onshore wind potential and the biomass potential are quantified based on a detailed analysis using a Geographic Information System (GIS). A broad range of different safeguard subjects, including e.g. different types of bird breeding areas or areas with different levels of soil erosion risk, are mapped against the respective spatial distribution of wind and biomass energy potentials. This allows quantifying the RES potential available for energy use as a function of the nature conservation criteria to be applied. The resource intensity and the availability of data limited this approach to specific case studies in Germany, from which we derived some more general conclusions. As in the case of hydropower ecosystem impacts depend on the respective characteristics of the water bodies and thus are even more site specific, we refrained from carrying out own modelling work, but organised an expert hearing on 'Hydropower and Nature Conservation' with participants from academia, industry, public bodies and non governmental organisations.

3 RES potentials in Germany under stringent nature conservation constraints

3.1 Wind

Figure 1 illustrates how the application of nature conservation criteria affects the wind energy potential in Baden-Württemberg, an inland region in the South of Germany with relatively low wind energy resources. Nature conservation criteria include among others the ban of wind turbines in nature conservation or landscape protection areas, Flora-Fauna-Habitat areas, bird breeding areas, as well as the consideration of hundreds of specific local scale biotopes or areas with a high visual sensitivity. It is obvious that nature conservation constraints significantly reduce the wind energy potential. However, depending on whether grassland and agricultural areas are considered suitable for wind energy use or not, the remaining potential in the Baden-Württemberg region amounts to 1,300 to 3,900 MW (for details see [2]). A comparison against the currently installed wind capacity of 230 MW (June 2004) suggests that nature conservation aspects are not the limiting factor for the further expansion of wind energy in Baden-Württemberg, a region in which policy opposition against wind energy is particularly strong today.

Similar results are derived for other case study regions, leading us to the conclusion that the wind energy potential is not primarily limited by nature conservation aspects, but perhaps more by visual intrusion impacts, and hence ultimately by public acceptance. The formal identification of ‘priority-areas’ suitable for wind energy use, which is under way in Germany on the community level, shows that the identified areas are considerably smaller than those areas that would be available even under stringent nature conservation criteria. A study for the State of Mecklenburg-Western Pomerania (North of Germany) [3] e.g. concluded that after excluding areas in the interest of landscape protection and habitat functions, approximately 5% of the land area is suitable for wind energy under nature conservation criteria, while only 0.5% of the land area was ultimately classified as suitable in the regional policy programmes. In Schleswig-Holstein, a coastal area in the north of Germany with significant wind resources, the suitable areas for the installation of wind turbines account for about 1 percent of the land area, while in inland regions this figure is considerably smaller, partly less than 0.1%.

To provide in our scenarios a perspective that takes account of increased social awareness regarding further extension of wind energy use, we assume that in future a total of around 0.5 % of the total land area in Germany will be available for wind energy utilization, with a larger share in the coastal regions and a significantly smaller share inland. Depending on the installation size, this results in a total onshore wind energy potential of 20,000 to 25,000 MW. Taking into account that the installed wind energy capacity in Germany already amounts to 15,330 MW (June 2004), a large share of the remaining potential is expected to be exploited by re-powering, i.e. the installation of large new wind turbines at sites currently occupied by smaller installations.

The expansion of offshore wind energy utilisation requires a particularly careful approach. Although we are gaining increasing experience from the first offshore installations operated throughout Europe (e.g. [4]), we still know little about the actual impacts from offshore wind parks on marine ecosystems. A large number of research and monitoring programmes is expected to improve knowledge, but reliable information on potential long term impacts will be available only after years. Since offshore wind energy utilisation constitutes a large-scale and long-term intrusion into the marine environment, the precautionary principle shall be applied by adopting a step-by-step expansion approach, in which each successive stage presupposes that results from the previous stage are positive and reliable in terms of compatibility with nature and the environment.

Taking into account nature conservation aspects (excluding e.g. Important Bird Areas) as well as different use interests (e.g. navigation, fishery, military use), the German Federal Government identified suitable areas for a first phase of offshore-installations, on which a capacity of 2,000 to 3,000 MW can be installed by 2010. It is expected that the offshore capacity will be expanded to 20,000 to 25,000 MW by 2030.

3.2 Biomass

Biofuels are obtained from a wide variety of biogenic resources originating mainly from agriculture and forestry, but also from landscape maintenance, industrial processes or households. Areas in which nature conservation and biomass production are completely mutually exclusive are confined to a small number of core areas of nature conservation, e.g. process protection areas in core zones of national parks. Competition for areas in the strict sense therefore plays only a secondary role in determining the potential for energy from biomass, the focus is rather on differences in the use of farmland, e.g. as arable or grassland. This refers in particular to the cultivation of perennial plants on agricultural land, which may be desirable from a nature conservation point of view on high erosion risk areas.

The underlying assumption for our biomass scenarios is that the demand for agricultural products is completely covered by domestic resources. This is justified by sustainability considerations, but it is not necessarily a realistic assumption taking into account future European and global developments. The starting point for determining the area suitable for biomass production is the today’s land use pattern, which will be affected by future more stringent nature conservation criteria. These changes however do not only result in the decrease of the biomass potential due to nature conservation constraints. In cases where nature conservation requirements result e.g. in the conversion of agricultural land into grassland, which in turn supplies biomass that can be used for energy generation, compliance with good nature conservation practice can in fact increase the available biomass potential.

The German Federal Nature Conservation Act [5] specifies the target of providing 10% of the German land area for establishing a supra-regional biotope network. On this area priority is given to nature conservation objectives, which however does not necessarily mean that biomass utilization is ruled out here. Figure 2 shows how in the year 2010 a set of agricultural sustainability targets specified by the German Government, including e.g. an increase in organic farming, the provision of area for a biotope network according to the Federal Nature Conservation Act, and the requirement for cultivating perennial crops on erosion risk arable sites reduces the area suitable for growing non-food crops from 2.5 Million hectares to only about 0.2 Million hectares. The resulting energy potential depends on the type of biomass, but it is obvious that nature conservation requirements cause a significant cutback of the available area. On the long term however this area grows again because of the expected reduction in the population, and a supposed increase in agricultural efficiency, leading to more than 4 Million hectares available for energy crop cultivation in Germany even under stringent nature conservation criteria in 2050.

In parallel to the restrictions discussed above, the realisation of nature conservation measures at the same time provide an additional biomass potential, as most of the nature conservation areas allow the production of biomass, including e.g. biomass from the maintenance of the edge of a forest, open land, biotope networks, and coppice or composite forests. The additional potential from biomass production on nature conservation areas and from the cultivation of perennial crops on erosion-risk sites amounts to 150 PJ/a (pie diagram in Figure 2), which is the same order of magnitude as the total biogas potential in Germany, and thus should not be neglected.

The additional biomass potential from solid residuals (e.g. forest wood, straw, industrial residuals, sewage sludge, etc.) under the Basis scenario amounts to 740 PJ/a in 2010, and remains nearly constant over time. Nature conservation constraints mainly affect the use of forest residuals, and limit the potential to 530 PJ/a in 2010. The potential for biogas obtained from fermentation of animal excrement and litter, from harvest residues, waste, and the potential of sewage and landfill gas is less sensitive to nature conservation aspects and amounts to 160 PJ/a under the Basis and 145 PJ/a under the NatureConservationPlus Scenario (see Figure 3).

Biomass can be used either for stationary generation of heat and power, or for producing biofuels for the transport sector. Due to the differences in yield, the total biomass potential depends on the share of stationary versus mobile biomass use. The energy potential of biomass crops is roughly twice as large for stationary heat and power generation as for the production of biofuels. The potential from residuals is nearly constant over time, while the potential from energy crops shows a significant increase until the year 2050 (Figure 3). In particular under the NatureConservationPlus scenario the availability of land area for cultivating energy crops indicates a possible time path for the expansion of biofuels in the transport sector. Over the next 20 years, the biomass potential from organic residues – regardless of whether or not nature conservation interests are taken into account – is considerably higher than from energy crops.

3.3 Photovoltaic and solar collectors

The construction and operation of building-integrated photovoltaic systems and solar collectors does not present any problems from a nature conservation perspective. More problematic is the installation of large scale PV plants on open land (‘green land’), which since the beginning of 2004 under specific conditions are also qualified for receiving feed-in tariffs under the German Renewable Energy Sources Act. Although the installation of PV plants does not lead to surface sealing as such - biodiversity on grassland covered with solar modules might be higher than on agricultural land - any installation on open land represents an additional impact on the ecosystem and increases space requirement, which should be minimised not only from a nature conservation perspective.

Our energy supply scenarios aiming at an 80% CO_2-reduction in Germany are far from making full use of the very large potential for the use of solar energy that exists within existing settlement structures (PV: 105 TWh_{el}/a, collectors: 360 TWh_{th}/a), so that from a capacity point of view there is no need to use open land for solar installations. It is most likely that the installation of large-scale PV plants on green land will intensify the problem of impacts from renewable energy installations on the natural scenery, and thus – similar to the case of wind energy – might lead to a discussion on the public acceptance of renewable energy technologies. This should be avoided by focusing on building integrated installations. Such a limitation at the same time is an incentive for the further development of concepts for the integration of solar modules into buildings and other settlement structures (e.g. noise protection walls).

From an industrial policy point of view large-scale open land installations may play an important role for a fast and cost effective expansion of the market volume. The German Renewable Energy Sources Act grants a feed-in tariff for large scale PV installations not integrated into building structures only if the plot of land was sealed before, is converted from economic or military use, or if it was used as cropland before. These limitations shall prevent negative impacts on sensitive ecosystems. Careful planning and the consideration of local conditions in individual cases can certainly minimise impacts, so that also a large scale installation on open land can comply with nature conservation requirements. Nevertheless, large scale open land installations should be considered only during the market introduction phase. They should be abandoned in the medium term to ensure public acceptance of solar energy. This by no means limits the expansion of solar energy use.

3.4 Hydropower

Environmental impacts from a hydropower plant depend on the local conditions and the technology in place. Although there is a strong public affection towards small-scale hydro plants, from an ecological point of view size does not matter that much, since neither ‘small-scale’ nor ‘large-scale’ hydropower in itself is ‘good’ to the environment. It makes more sense to differ between the level of impact, which apparently is different for building new plants at semi-natural rivers, new plants at sites already in use, or the re-activation or modernisation of existing hydro plants. Building new small-scale hydropower plants may have greater adverse environmental effects than modernising an existing large-scale power plant.

While the hydropower potential in Germany is largely exploited, the greatest contribution to further increase electricity generation from hydropower can be achieved by modernizing existing large hydropower plants. Modernisation should always go along with improvements in the ecological situation of the river. If the construction of new hydropower plants on semi-natural rivers is completely excluded, this reduces the potential for further expanding hydropower by about 1 TWh/a. Compared with the total potential for renewable energy in Germany this reduction is negligible, but it mainly affects potential sites for new small-scale hydropower plants.

3.5 Geothermal energy

To ensure the sustainable use of geothermal power as a resource, the technical potential shall only be developed gradually over a long period owing to the low level of the natural heat flow. Given a development period of 1,000 years, the technical supply potential in Germany is about 300 TWh_{el}/a [6]. If we go for the economic beneficial cogeneration of heat and electricity, restrictions on the demand side of the heat market limit this potential to 65 TWh/a. Just like other forms of energy conversion, the utilization of geothermal energy represents an interference with the natural equilibrium of the environment, in this case the upper Earth's crust. Present knowledge indicates that the consequences of possible impacts, such as a potential hydraulic short-cut between different underground layers as a result of drilling, are small. Cooling of the underground will lead to changes in the chemistry of the reservoir and possibly to microseismic symptoms. Since this takes place at great depth and there is generally no connection with the biosphere, no impacts on flora and fauna are known to date. In view of the lack of experience, however, such effects should be the subject of careful review in the future.

3.6 Total RES-potential in Germany under nature conservation constraints

The potential for the use of renewable energy sources in Germany under the two different scenarios 'Basis' and 'NatureConservationPlus' are summarised in Figure 4. While the more stringent constraints under the NatureCosnervationPlus Scenario reduce the potential in particular for onshore-wind and biomass by up to 40%, the total RES-potential available in Germany is only slightly affected. In Germany today only a small share of the RES-potential is exploited, so that for all types of renewable energy sources there is still a vast potential for expanding their use even under the constraints of nature conservation aspects.

Results clearly indicate that the long term expansion of renewable energies as required to achieve the 80% CO_2-reduction target in Germany is definitively not in conflict with nature conservation requirements. The total RES-potential is sufficient to satisfy a large share of the today's energy consumption in Germany (Figure 5). The important role of renewable energies becomes even more evident when taking into account the large potential for energy efficiency measures in all energy demand sectors. Efficiency strategies in particular in the heat and transportation sector will render a significant reduction of energy demand, which in turn leads to a growing share of renewables to primary energy supply.

4 Effects of nature conservation constraints on long term RES-strategies in Germany

While in the previous section we concluded that the total RES potential in Germany is sufficiently large to go from the current 3% share of renewables to primary energy consumption to at least 50% by the mid of the century even under stringent nature conservation requirements, we also noted that there are some limitations on specific renewable energy sources, in particular on wind and biomass. To ensure that current strategies are directed towards a long term sustainable use of renewable energies, these limitations need to be carefully reviewed in the light of related policy targets.

As discussed above, the application of nature conservation criteria at least on the short term has a strong impact on the availability of arable land for growing energy crops, which in turn has implications on the production of biofuels. To foster market introduction of biofuels, the European Commission set out the target that by 2010 biofuels shall reach a minimum share of 5.75% of the total automotive fuel market [7]. Figure 6 illustrates the area required to achieve the 5.75% target in Germany by producing biofuels from different energy crops.

This area requirement is compared against the area available for growing energy crops in Germany under the Basis and NatureConservationPlus scenarios. If biofuels should be produced from domestic biomass resources in Germany, even under the Basis scenario with less stringent nature conservation requirements it is difficult to achieve the European target, while under the NatureConservationPlus scenario it is completely out of reach. As discussed above, on the long term there is a much larger potential for energy crops because of the increasing availability of land suitable for biomass production, but on the short term there is an obvious bottleneck, which should be carefully respected in the design of RES policy strategies. Before forcing renewable energies into the transport sector, the substantial and more cost-effective potential for reducing energy demand shall be exploited. Any strategy that attempts to replace fossil fuels in the transport sector without making substantial changes in the mobility structure and vehicle specific energy demand is not considered as a viable option.

Figure 7 shows how nature conservation constraints affect the expansion of renewable energies in the German electricity sector under the 80% CO_2-reduction scenarios. Compared to the current electricity supply structure, the contribution of centralised condensing power plants is reduced to only 30 TWh/a, while the share of combined heat and power generation and from renewable energy sources grows rapidly, leading to a diversification of mainly decentralised energy sources [1].

While until 2030 the differences between the Basis and NatureConservationPlus scenarios are very small (less electricity from onshore wind under NatureConservationPlus), in 2050 the total electricity generation in the NatureConservationPlus scenario is about 15% higher than in the Basis scenario. For cost efficiency reasons in the NatureConservationPlus scenario the limited amount of biomass is primarily used in stationary applications for heat and electricity generation, resulting in an additional demand for CO_2-free fuels in the transport sector, which is covered by hydrogen from RES-electricity. This increased demand for electricity is produced from offshore wind, geothermal and PV installations, but also from imports of RES-electricity, mainly from concentrating solar thermal power plants in North Africa.

As reported also by other scenario studies, the active market introduction of renewable energies on the short term leads to additional costs to the national economy, which requires specific policy support to overcome market barriers. Depending on the development of fossil fuel prices and on the learning effects that are expected to reduce the costs of renewable energy technologies, on the medium to long term (i.e. 2030 to 2050) energy supply costs from a supply system with a high share of renewables fall below those of a fossil-based business-as-usual scenario, so that renewable energies on the long term contribute to a stabilisation of energy costs [1]. Our analysis shows that in spite of the more stringent nature conservation requirements the total energy supply costs (electricity, heat and transportation fuels) are lower in the NatureConservationPlus scenario than in the Basis scenario for the next three decades, because we abandoned the costly 5.75% biofuel target for nature conservation reasons. On the long term however – as one might have expected – the total energy supply costs are about 30% higher under the

NatureConservationPlus scenario, which is mainly due to the need for producing hydrogen as a CO_2-free transportation fuel from RES-electricity.

5 Conclusions

The stabilisation of atmospheric CO_2-concentration requires major CO_2-reduction efforts all around the world. The exploitation of energy efficiency potentials and the increasing use of renewable energies are considered as key strategies for achieving global CO_2-reduction targets in a sustainable way. In most countries however, there is still quite a long way to go to establish renewable energy sources as a major energy supply source. In Germany, where feed-in tariffs for RES-electricity successfully stimulated a dynamic growth of renewable energies over the last decade, we had to observe also an increasing public concern towards the potential impacts from RES-technologies on local ecosystem and the natural scenery, leading to the question on whether the contribution of renewable energies to climate protection is at the expense of nature conservation. The results of our study show that at least in Germany the ambitious long term target for expanding the share of renewable energy sources from currently 3% of primary energy consumption to 50% in 2050 can be realised without getting in conflict with nature conservation requirements. Potential areas of conflict between the use of renewable energy technologies and nature conservation of course exist, in particular in the case of wind energy, biomass cultivation, hydropower, and probably also for solar installations not integrated into settlement structures. Constraints from a nature conservation perspective shall be carefully respected when designing RES-expansion and CO_2-reduction strategies, in order to not raise the impression that there is an inevitable trade-off between climate protection and nature conservation. To ensure long term societal acceptance and public support for renewable energy technologies, we thus strongly suggest to develop RES-strategies under the most stringent nature conservation criteria. In the future, more emphasis should be given in developing harmonised trans-European strategies for the use of renewable energy sources to make full benefit of the environmental and also economic advantages of the complementary nature of renewable energy sources all over Europe and North Africa.

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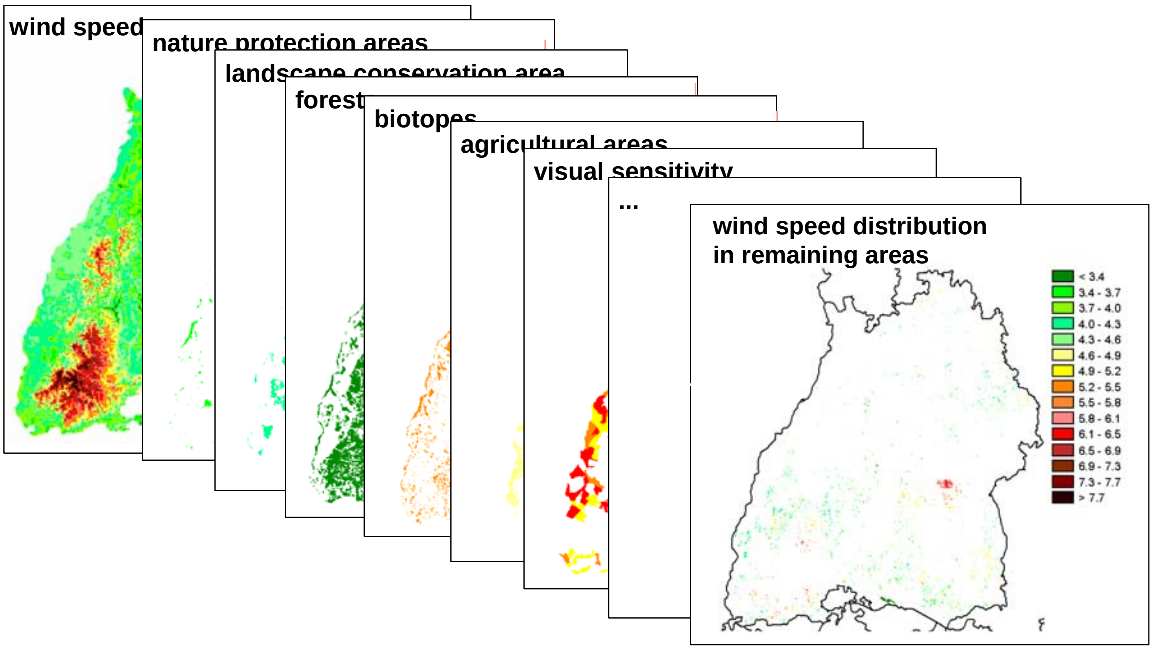

Figure 1: GIS-based estimate of wind energy potential under the constraints of nature conservation criteria (case study of Baden-Württemberg, South of Germany)

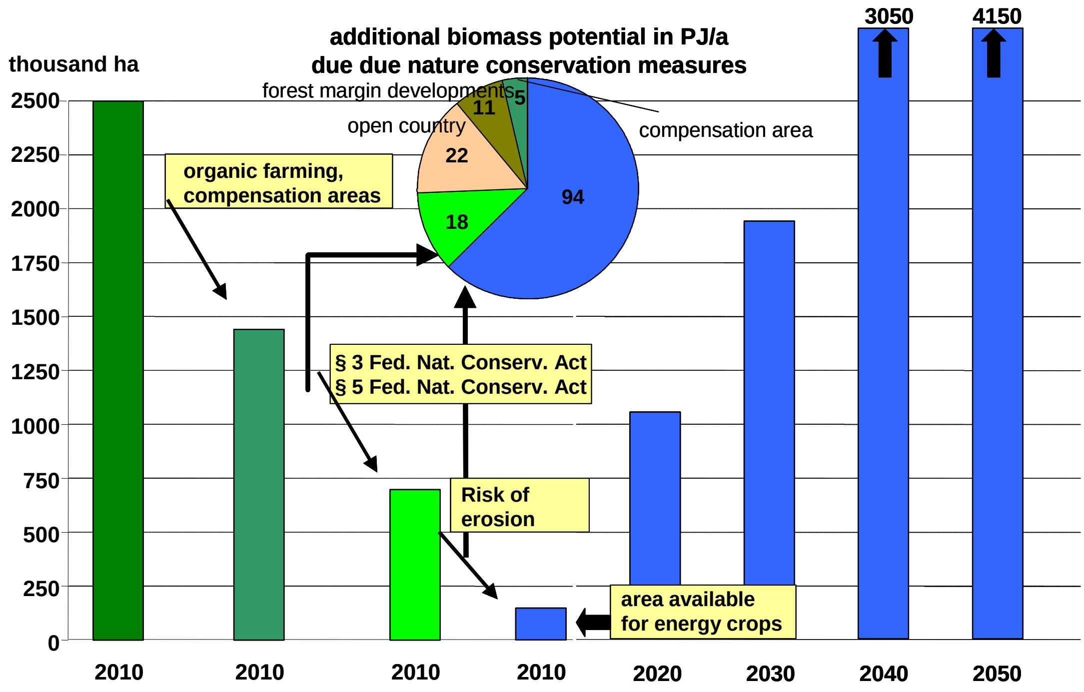

Figure 2: Reduction in land area available for biomass production from the application of different nature conservation criteria; resulting additional biomass potential (150 PJ, pie chart); and subsequent increase of the remaining area over time

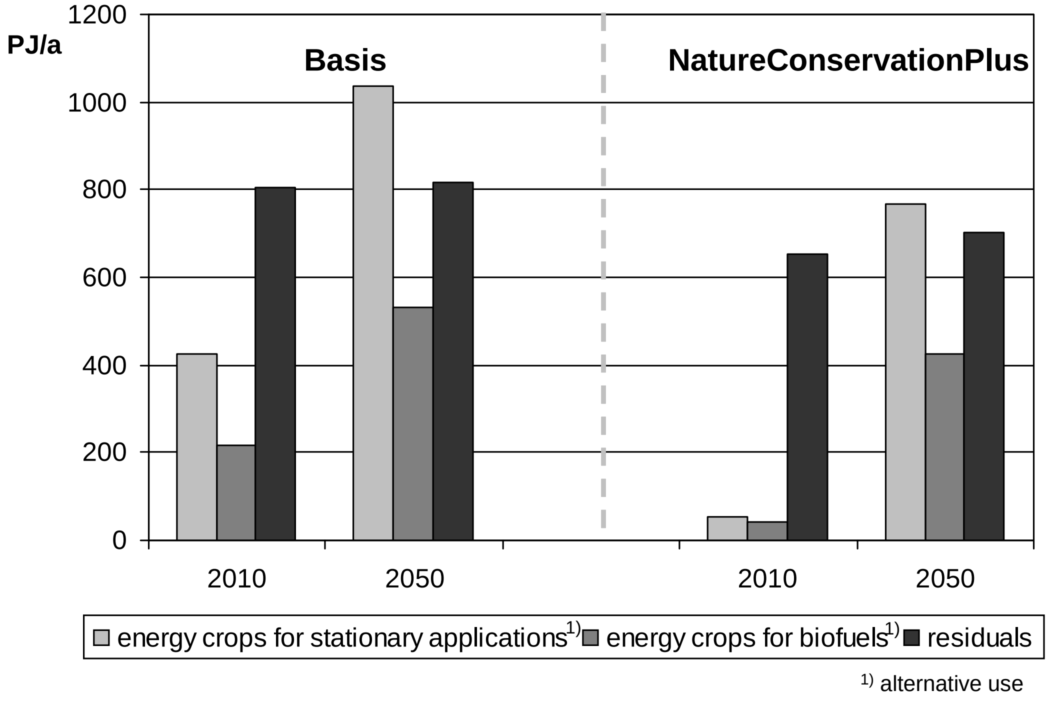

Figure 3: Development of the biomass potential in Germany over time, taking into account different use options, and different nature conservation criteria

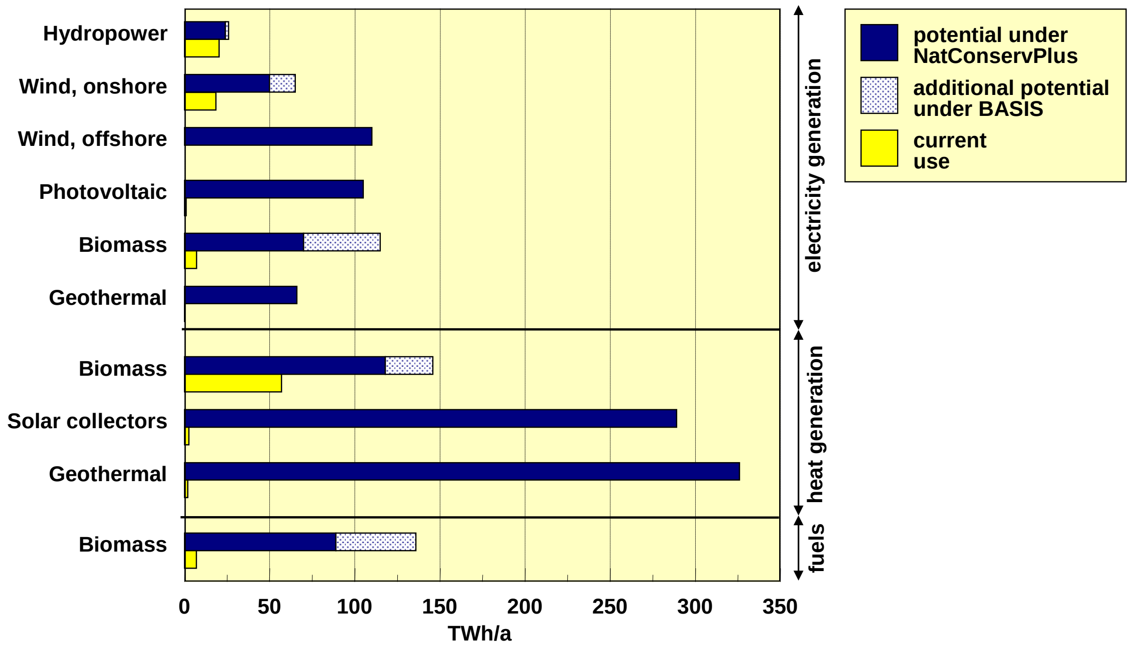

Figure 4: Renewable energy potential in Germany under the BASIS and NatureConservationPlus scenario (base year 2050)

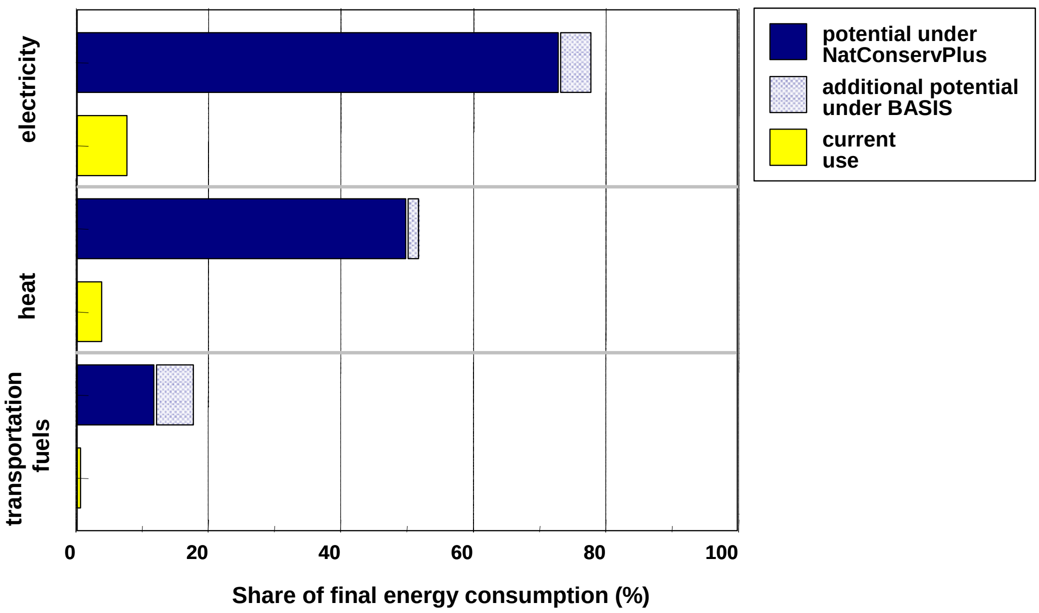

Figure 5: Potential for the use of renewable energy sources in Germany related to final energy consumption in 2003

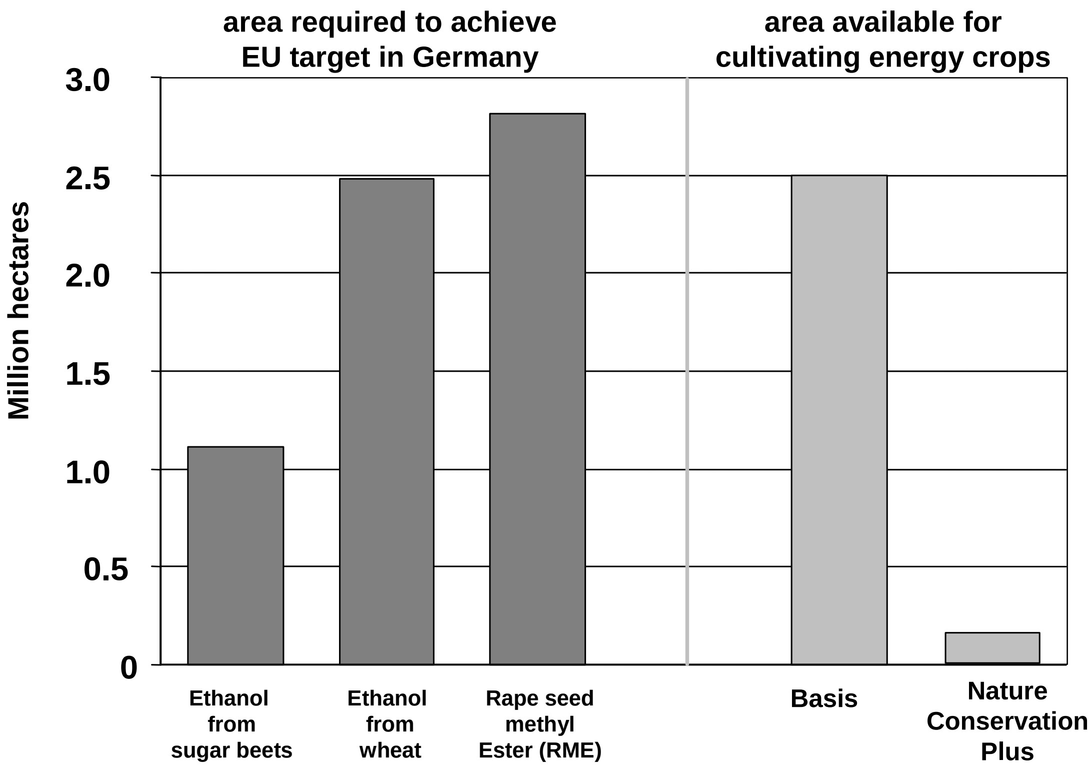

Figure 6: Area required for growing energy crops in Germany to achieve the EU target of 5.75% biofuels in 2010, and area available for growing energy crops under the Basis and NatureConservationPlus scenarios in 2010

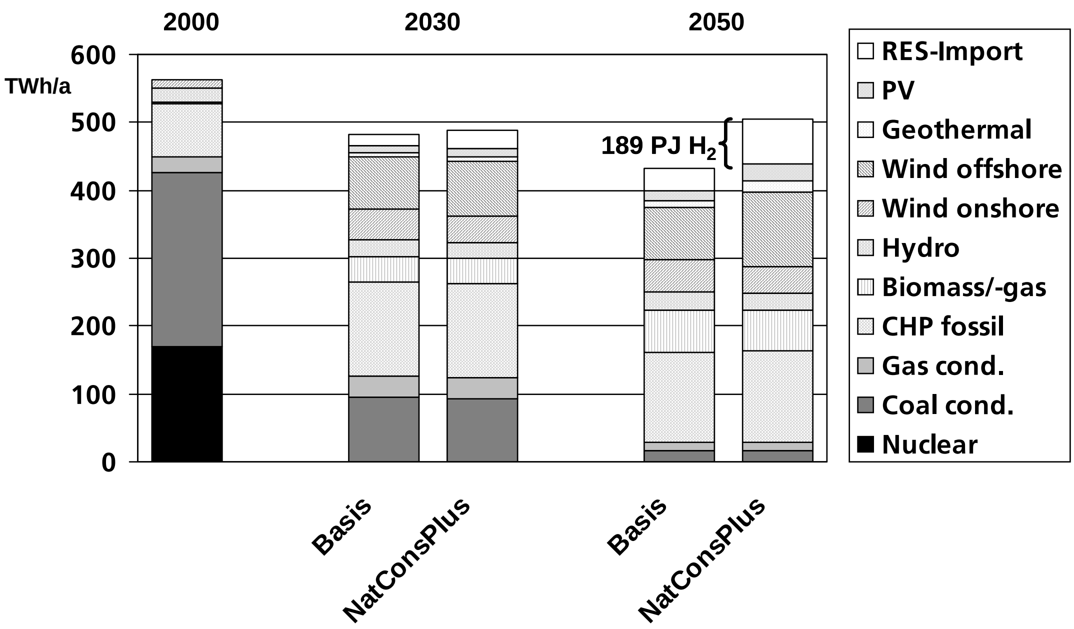

Figure 7: Long term RES-expansion strategies in the German electricity sector under different nature conservation constraints